Increasing Mobility and Reducing Bulk of Combat Uniforms Through Engineered Fabrics with LYCRA®

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Today's Warfighter

- ***Too Heavy***
- ***Too Bulky***
- ***Equipment Interference***
- ***Limited Operational Capability, Mobility, and Survivability***

- ***Future Force developments and Lessons Learned studies reinforced the need to reduce weight and bulk.***

Legacy Combat Clothing

- Combat clothing is engineered to provide the warfighter with the greatest range of motion to accommodate the unique activities across a broad range of warfighter missions.
- Engineered to be big, bulky and baggy.
- Sized generously to assure proper fit and accommodate the greatest percentage of the warfighter population.
- Drawbacks of providing this performance with rigid fabrics:
  - Increases overall garment weight and
  - Contributes to discomfort, heat stress, and reduced mobility.

New Material Technology

- New material technology engineered for stretch and recovery is available that enables the development of combat clothing with:
  - Trimmer silhouette,
  - Reduced bulk and garment weight,
  - Improved fit and comfort, and
  - Unrestricted ease of movement.

- New streamlined designs can ultimately provide a significant payoff in overall garment weight reductions of 10-35%.

Objectives

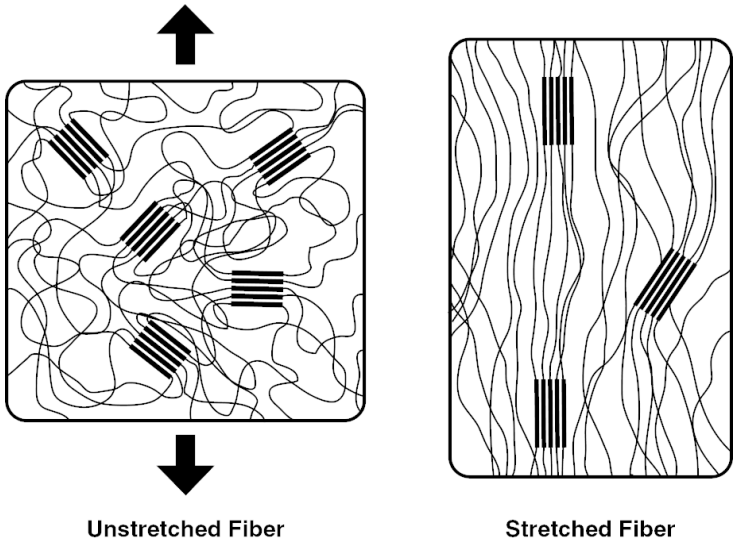
- Develop combat uniforms with LYCRA® elastane.
- Determine stretch levels appropriate for combat applications.
- Identify warfighter perceptions, attitudes,and opinions about the wear and use of streamlined combat clothing to insure user acceptability.
- Develop test methods and standards for fit, comfort, and range of motion for combat clothing made with fabrics with elastic fibers.

Evolution of Elastane Fiber

- Three fiber developments transformed textiles of the 20th century:
  - Man-Made Cellulosics
  - Synthetic Fibers
  - Synthetic Elastomeric Fibers
- With the vision of creating fibers that emulated and improved upon the functionality of natural fibers, polymer chemists began searching for elastic fibers to replace rubber in 1944.
- Exploration focused on elastomeric block co-polymers with greater tensile strength, higher modulus, and higher chemical stability than rubber.

Discovery of LYCRA® Elastane

- Shivers discovered polyurethane fibers with polyurea-urethane polymer chains made of:
  - "Soft" amorphous segments with chain molecules providing elasticity, and
  - "Hard" segments forming crystallite structures
  - Creating the block and spring polymeric structure.



Evolution of Major End-Uses

1960s	1970s	1980s	1990s
Foundations	Swimwear	Hosiery	Ready to Wear
Waistbands	Intimate Apparel	Activewear	Sportswear
			Knits
			Childrenswear
			Menswear

- As a new fiber class, elastanes catalyzed the development and growth of new fabric and garment types with improved comfort and fit.
- Finer deniers, higher modulus, superior chemical and environmental resistance led to the creation of thinner, lighter weight garments with the same holding power and drove the early replacement of rubber.
- However, weaving presented difficult technical challenges.

Evolution of Major End-Uses

- Modern weaving operations present special demands on elastic properties due to cyclic high speed yarn acceleration, high tension peaks, and short term friction surges.
- Technology advances evolved over the 1990s:
  - Yarn Covering techniques
  - Tension Control
  - Engineered Fabric Construction
- Enabling development of the first combat uniform fabric made from NYCO with LYCRA®.
- Knowledge gained over the last four decades in engineering fabrics and garments with elastane fibers provides the fundamental principles and baseline for development combat uniforms made with elastane fibers.

Biomechanics of Fabric and Garment Mobility

- Kirk and Ibrahim defined the fundamental relationships between between elastic garments and physical movement.
- Skin stretches when you move.
- Once skin stretch is understood, then the fabric stretch level can be defined to fit the body demand.
- The next step is to determine if clothing is worn away from the body.
- Garments worn close to the skin need stretch levels comparable to skin stretch for unrestricted movement.
- With increasing space between the body and garment, other factors play an increasing role.

Biomechanics of Fabric and Garment Mobility

- Knee, Seat, Back and Elbow are critical stretch areas during body movement.
- The skin stretches in both the vertical and the horizontal directions.
- Even for people of different shapes, weights, and sizes, the percentage of skin stretch is very constant.

Skin Strain (%) in the Horizontal x Vertical Directions under Typical Movements

Knee: 29% x 49%, Stand → Deep Bend;

Seat: 41% x 45%, Stand → Bend;

Back: 47%, Shoe Tying;

Elbow: 24% x 50%, Straight → Full

Biomechanics of Fabric and Garment Mobility

- The next step is to determine if clothing is worn away from the body.
- Garments worn close to the skin need stretch levels comparable to skin stretch for unrestricted movement.
- With increasing space between the body and garment, other factors play an increasing role:
  - Ratio of Garment Size to Body Size
  - Coefficient of Fabric Friction
  - Number of Contact Points
  - Fabric Stiffness
  - Fabric Stretch
  - …

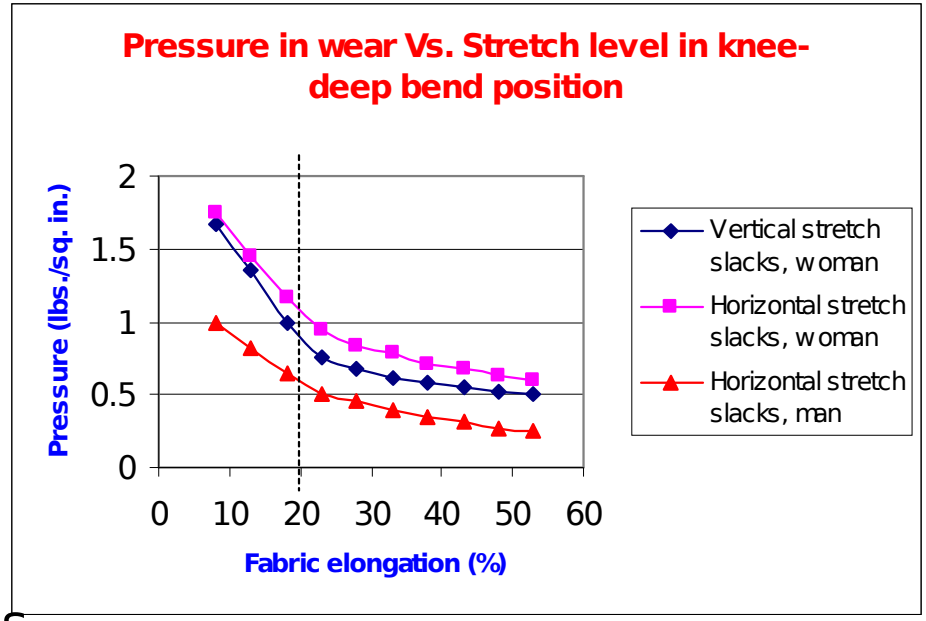
Fabric Development

- A study is underway between NSC and INVISTA to determine the level of fabric stretch required in a streamlined combat uniform to enhance mobility, comfort, and fit.
  - Phase I: To develop range of stretch levels incorporating LYCRA® elastane into NYCO (50/50 T420 nylon/cotton) in the twill construction used in temperate uniforms
  - Phase II: To optimize tensile strength and growth performance.
- Designed three fabrics with stretch levels ranging from 30-45%.
- Stretch level was selected based on the known needs of everyday use and more demanding needs for combat functions.

Initial Stretch Level Selection

- If woven fabrics have greater than 20% fabric elongation, the garment is less restraining and more comfortable with freedom of movement for the wearer.

- A rapid drop in pressure or strain on the knee occurs in going from a non-stretch to a stretch garment.
- This drop continues until a fabric with up to 20% stretch is worn.
- The pressure drop flattens out and remains low with higher available stretch levels.

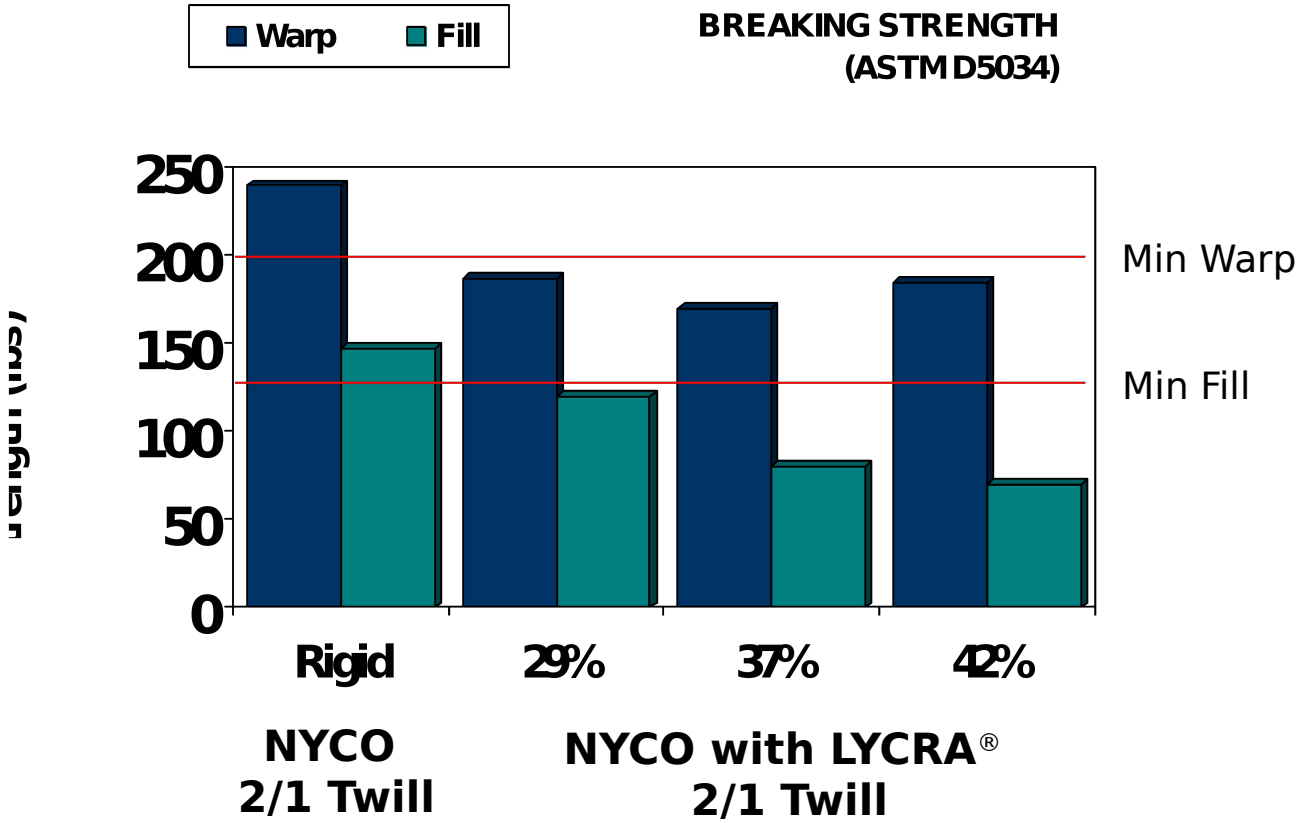


Involved over 3000 yards of fabrics, 800 garments, 500 subjects and over 250,000 test points

NYCO with LYCRA® Fabrics

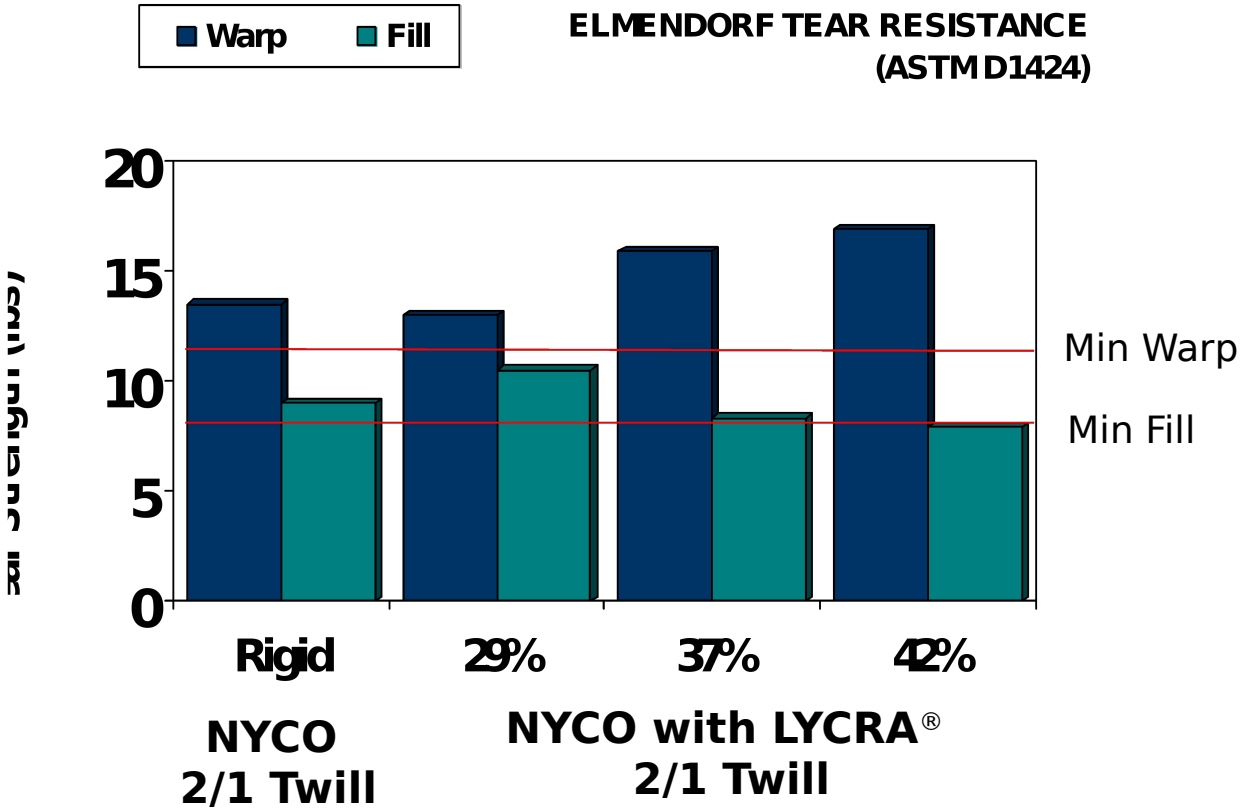
- LYCRA® elastane can stretch up to 700% and recover instantly.
- With its high power and recovery, only a small amount of LYCRA® (3%) is required to enable garments to move with the natural motion of the body.
- The primary NYCO fibers compose 97% of the fabric.
- Fabrics enhanced with LYCRA® retain the functionality and performance of the primary fibers:
  - Natural appearance and hand
  - Durability
  - Superior colorfastness
  - Comfort
- Fabric development with LYCRA® is aimed at comparable or greater durability than 100% NYCO fabrics.

Breaking Strength



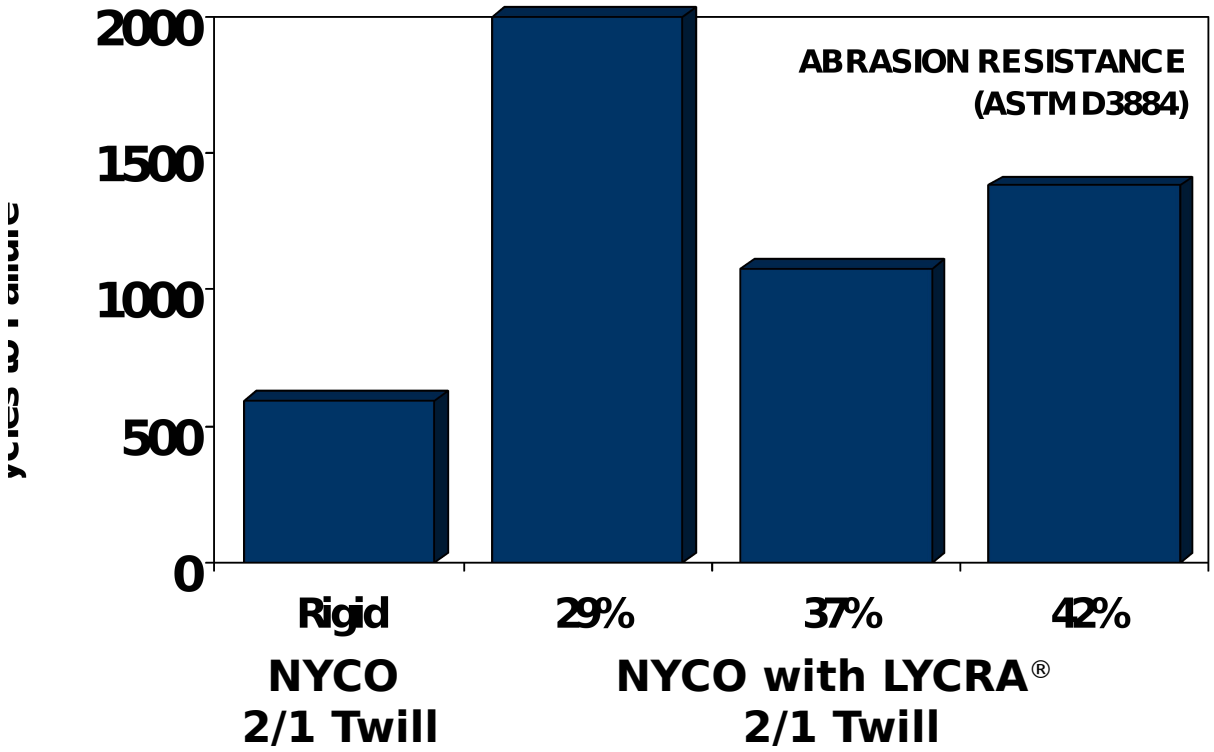
- Breaking Strength is slightly lower than 100% NYCO.
- With the insertion of LYCRA® in the fill, the breaking strength in the fill direction is inherently reduced over 100% NYCO.

Enhanced Tear Resistance



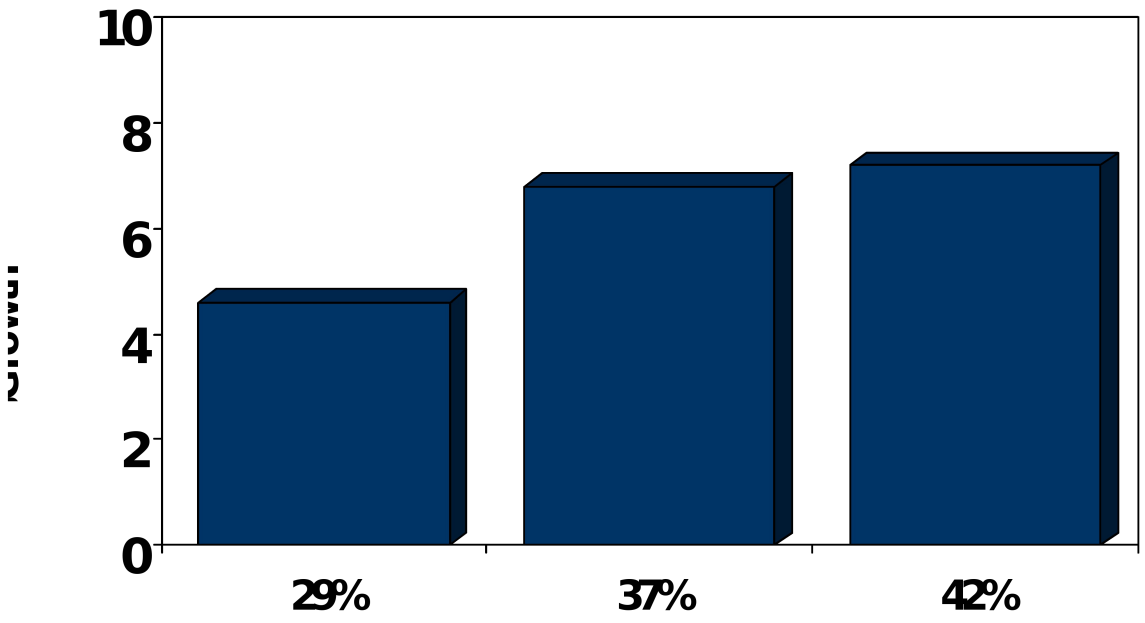
- When a fabric with LYCRA® elastane catches on an object, the fabric stretches further and can release before the tear occurs.

Enhanced Abrasion Resistance



- LYCRA® elastane enables the fabric to move away from the abraded object so abrasion is not concentrated on the same point.

Growth (Recovery)



NYCO with LYCRA® 2/1 Twill

- Growth = Unrecovered stretch during extended wear.
- The higher the stretch, the lower the fabric recovery.
- Even though fabric growth recovers in washing, growth should be minimized to maintain garment's original shape and fit during wear.

Focus Group: Fabric Swatches

- NSC conducted a focus group with 10 male and female military personnel assigned to Natick.

Key Elements of Response:

Opinions of Current BDU and BDU Fabric:

Likes	Dislikes
Durability	Costly to dry clean
Lightweight	Restricts the knee during bending
Breathability	Too much fabric to tuck into the boots
Does not dirty easily	
Does not bind	
Freedom of Movement	
Sleeves roll up easily	

Focus Group: Key Elements

Opinions of New Fabrics with LYCRA® :

- Favorable toward the sensory tactile properties.
  - Softer and more comfortable.
  - Lighter weight.
  - Thinner.
  - Easily perceived one directional stretch.
- Stretch could add important flexibility to aid in certain body movements, such as bending.
- Lighter weight perception led to importance of maintaining durability and environmental comfort (cooler in summer and need insulation in winter).

Focus Group: Key Elements

Attitudes Toward Form-Fitting Combat Uniforms:

- Less bulk beneficial in reducing tendency to catch on objects.
- Should not be too tight.
- Not favorable toward a totally form fitting silhouette.
  - Too revealing.
  - Less tolerance for weight gain.
  - Weight changes may lead to size changes and the need to replace the uniform more frequently.

Future Work

- Conduct anthropometric and human factors studies in garment form.
- Create streamlined combat uniform with Natick IPD Design and Prototype Facility.
  - Maintains two piece combat uniform design, all current design features, and sewn construction.
  - Consider each garment component, direction of stretch, current design, sizing and grading to streamline space and maintain ease of movement.
  - Streamline garment patterns.
- Establish test protocol to assess comfort and mobility through a series of actions to assess comfort.
  - Subjective evaluations in range of motion evaluations.
  - Novel quantitative measurement technology to quantify dynamic pressure exerted on the body by the uniform during various movements.
  - Correlation of quantitative comfort data with subjective individual assessments.

Conclusions

- Improvements in weight and bulk are central focuses of the U.S. Army's continual spiral upgrades.
- Combat uniforms made with LYCRA® elastane will improve mobility and allow for a lighter weight, streamlined combat uniform.
- Applying this technology at a systems level will enhance improvements in weight and bulk beyond the combat uniform itself.
- Engineered fabrics and uniforms with increased mobility will enable the military to achieve its objective:
  - ➔ Reduced weight and bulk with improved fit, comfort and durability.

Partnering & Leveraging: To The Next Level

- Strategic Partnerships –
  An Integral Part of Our Program/Project Structure:
  - Actively Leverage Industry, Academia, and Other Government Agencies to Enhance NSC Core Competencies
  - Leveraging Technology Hub Location & Maximizing CRADA Opportunities
  - Leveraging Customer Funding/Acquisition Process Initiatives

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